



16-07

MAY 2016

Assessing Root Disease Presence, Severity and Hazard in Northern Idaho and Western Montana Using Forest Inventory and Analysis (FIA) Plots and the USFS Northern Region VMap Database

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Introduction

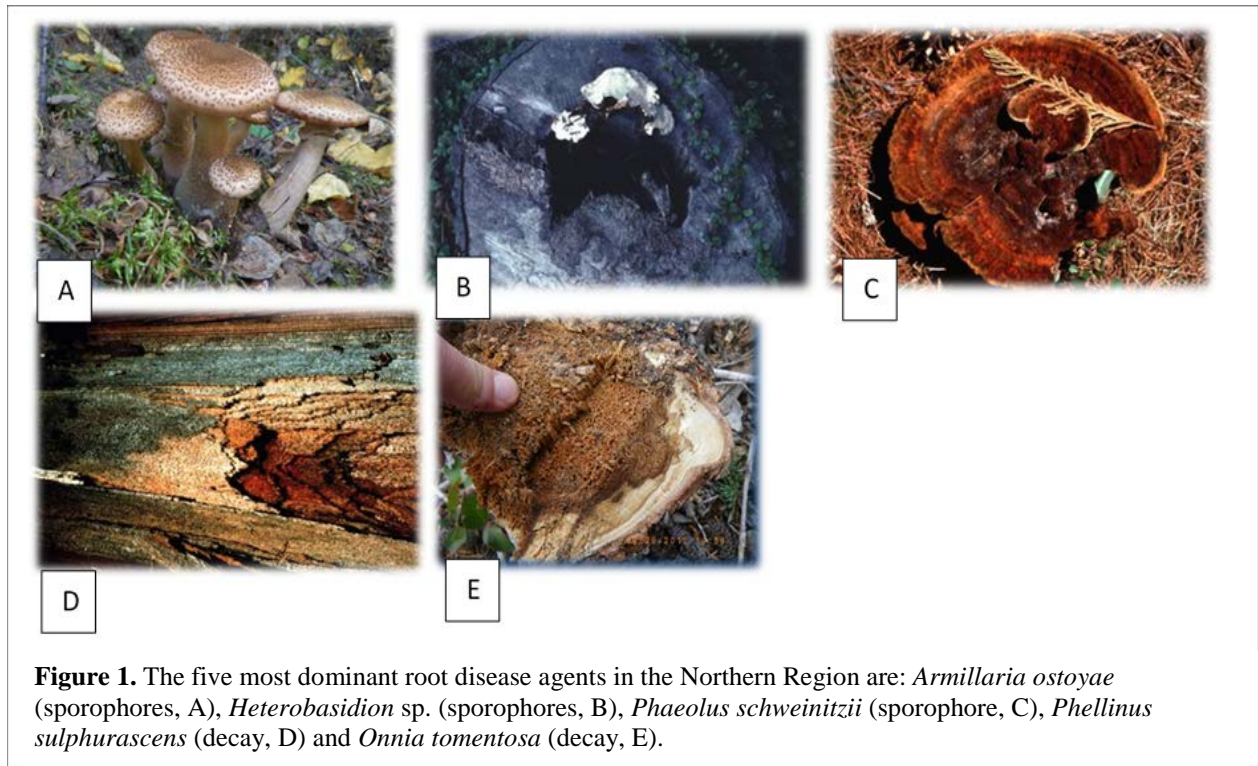
Forest Health Protection is responsible for assessing forest insect and disease activity on forested lands. Aerial detection surveys (ADS) provide data on insect-caused damage such as bark beetles and defoliators, but assessing root diseases cannot be accurately done through ADS, so other means need to be employed.

The 2012 National Insect and Disease Forest Risk Assessment (NIDFRA; Krist and others 2014) includes models for risk from root disease, and is the best information available for incidence and severity of root diseases at the national scale. At the multi-state scale, several efforts have used aerial photo interpretation to assess root disease hazard (or risk) on National Forest lands in northern Idaho and western Montana (Hagle and others 2000). In this report we use root disease data collected on the Forest Inventory and Analysis (FIA) sub-plots on National Forest lands to assess the presence and severity of root disease in northern Idaho and western Montana within the USFS Northern Region.

The principle root diseases impacting forests in the Northern Region are Armillaria root disease (*Armillaria ostoyae*), Heterobasidion root diseases (*Heterobasidion occidentale* and *H. irregulare*), laminated root rot (*Phellinus sulphurascens*), and schweinitzii root and butt rot (*Phaeolus schweinitzii*). The Region is also beginning to record the presence and impact from tomentosus root rot (*Onnia tomentosa*) (Figure 1). In northern Idaho and western Montana, multiple root disease agents can co-exist making separation of impacts by agent difficult.

Our evaluation assesses the presence and severity of root diseases using data from FIA sub-plots in northern Idaho and western Montana, and develops a spatial depiction of root disease hazard across the same landscape using available spatial data. Note that root disease severity is the actual measurement of root disease on an area basis, while hazard is defined as the probability of root disease existing within a defined vegetation class (See page 5).

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Methods

Root disease severity from FIA sub-plots

Hagle (1992) developed a system to rate the severity of root diseases on permanent plots installed in the western half of the Northern Region. The rating system is based on canopy loss due to root diseases and/or the ground occupied by root disease pathogens. This evaluation is based on above ground symptoms, and takes into account the tree densities that would normally occur on the site. Thus, a site that normally has a lower density due to poor growing conditions would be evaluated based on that lower density. The root disease severity rating system is the basis for assessing root disease in this analysis.

This method of evaluating the severity of root diseases uses a 0 to 9 rating system that can be applied at the plot level or the stand level; it is meant to be a quick and easy way to assess root disease impacts (Figure 2; Hagle 2011). A rating of 0 indicates that no evidence of root disease was noted on or near the plot. A rating of 1 means there is evidence of root disease near the plot, and a rating of 2 means there is minor evidence of root disease on the plot with up to 10% canopy loss. The rating increases with increased canopy loss and/or ground occupied by root pathogens, with the highest rating of 9 given to a plot that falls entirely within a root disease mortality pocket with all overstory trees dead due to root disease. Permanent plots installed to monitor root disease impacts (Hagle 1985) have shown that mortality rates for root disease-susceptible tree species have been positively correlated to root disease severity ratings (Hagle and others 2016).

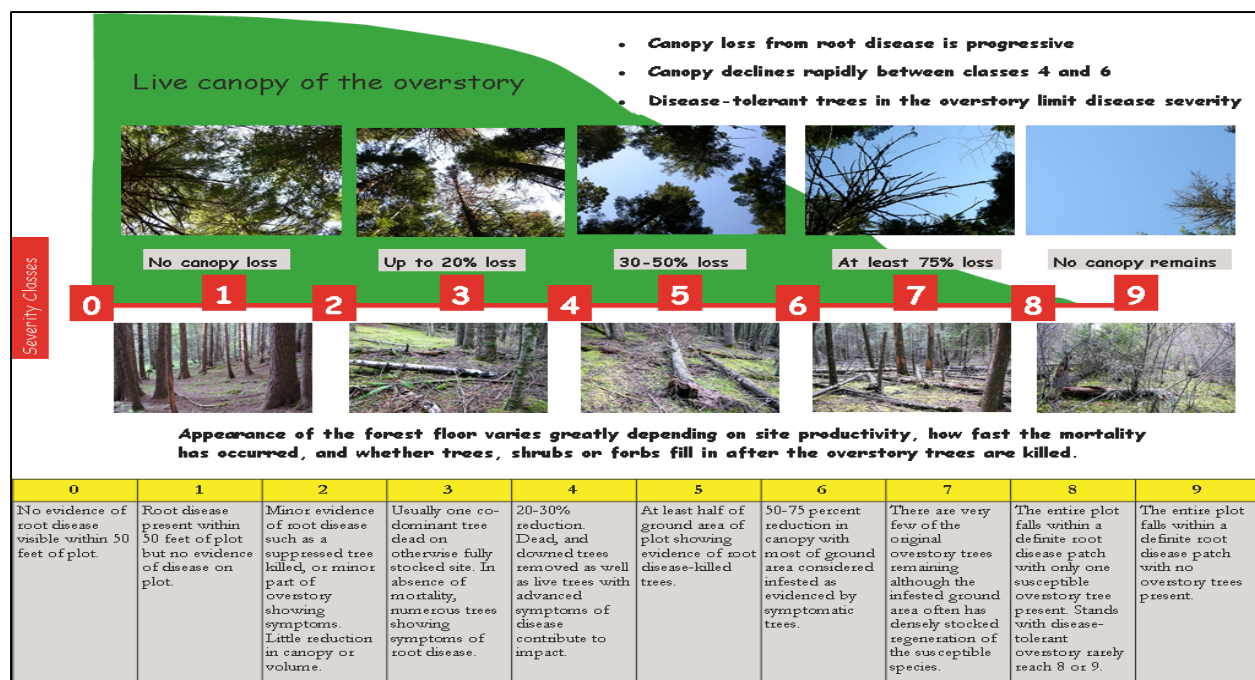


Figure 2. Root disease severity is based on canopy loss due to root disease (Hagle 2011).

Root disease severity is collected at the sub-plot level on all FIA plots measured in the Northern Region (Anon. 2013, p. 102). FIA is a statistically based, continuous inventory of forest resources in the U.S. The FIA annual inventory was implemented in Montana in 2003 and was started in Idaho the following year. With the annual inventory, approximately 10% of all FIA plots in a state are re-measured each year, with a full measurement on all plots occurring every 10 years.

Annual FIA sub-plot remeasurements were used for this analysis. Although the data set does not yet include all 10 years of measurements, it provides a spatially and statistically sound sample across the Northern Region. The full 10 years of annual remeasurements are not yet available for data analysis. This analysis is for forests west of the Continental Divide (Figure 3). Root disease is a significant agent in localized areas on forests east of the Continental Divide, but less knowledge exists on how well the severity rating system reflects root disease activity in these biophysical environments.

Root disease severity collected by the FIA crews in the field were collapsed into 4 classes for this analysis: None (rating of 0), Low (ratings 1 and 2; up to 10% canopy reduction), Moderate (ratings 3 to 5; between 10% and 50% canopy reduction) and High (ratings 6 to 9; 50% or greater canopy reduction) classes.

The FIA sub-plots were then combined into unique classes of Bailey's Ecoregion, forest dominant type, and potential vegetation type for further analysis. Bailey's ecoregions are geographic areas that are delineated based on factors such as climate, physiography, water, soils, air, hydrology, and potential natural communities (Bailey 1995; Figure 3). FIA sub-plots were attributed with the ecoregion where they were located. Earlier analyses of root disease in the Northern Region detected a difference in root disease levels by ecoregion (Hagle and others 2000).

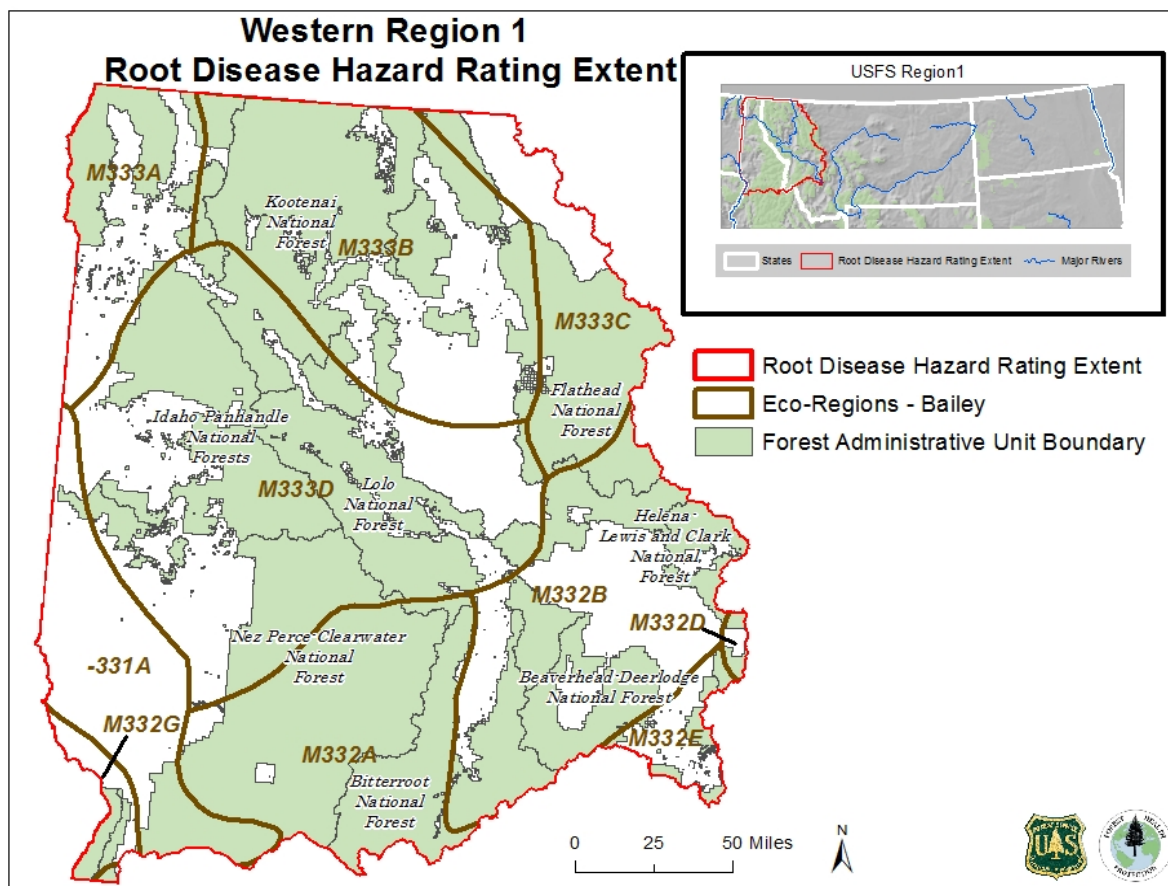


Figure 3. Root disease analysis area boundary, including Bailey's Ecoregions and National Forest boundaries.

The R1 Existing Vegetation Classification for Tree Dominance type 40% plurality (DomMid40) was used for classifying forest dominant type in this analysis (Barber and others 2011). A single-species label is applied if that species has at least 40% abundance; otherwise, mixed types are classified by species life form sub-class, such as hardwood mix, shade intolerant mix, and shade tolerant mix based on all the trees occurring on the sub-plot. DomMid40 can be applied to inventory data, such as FIA, and is also mapped using the R1 Vegetation Mapping Program (R1 VMap). R1 VMap is a database of existing vegetation derived consistently across the region with an associated accuracy assessment (Barber and others 2012). It is a remote-sensing based product that uses Landsat and National Agriculture Imagery Program (NAIP) imagery and biophysical criteria. (More detailed information on Northern Region VMap can be found at this website: <http://www.fs.usda.gov/goto/r1/VMap>). DomMid40 was determined for each FIA sub-plot and attributed accordingly.

Potential Vegetation Types (PVTs) are groupings of potential vegetation habitat types having similar biophysical environments, such as climate and soil. Earlier work in the Northern Region documented a correlation between presence and severity of root disease and habitat type series (Byler and others 1990). PVT Groups can be effectively mapped to show spatial extent on the landscape. Mapping potential vegetation from imagery alone is impossible, and modeling it with biophysical surfaces and climate data is not trivial. Currently, the only consistently derived

contiguous layer of potential vegetation is the *R1 PVT layer*, also known as the “Jones” layer, which was developed for the Cohesive Strategy in 2004 utilizing multiple data sources (Milburn and others 2015). In some cases the classification differs for types in Montana versus Idaho. The cross-walk between field recorded habitat type and the R1 PVT Groups developed by Jones is documented in *R1 Inventory Data Look-up Tables Database* (Anonymous 2015), and depicted in the *Region 1 Existing and Potential Vegetation Groupings used for Broad-level Analysis and Monitoring* (Milburn and others 2015). Each FIA sub-plot was attributed with a PVT Group based on habitat type collected on the sub-plot.

Root disease hazard calculated from severity

The relationship of root disease hazard by DomMid40, PVT Group, and Bailey’s Ecoregion was then explored using the FIA inventory data. Root disease hazard is defined as the probability of root disease existing within a defined vegetation class. A rule set for assigning root disease hazard to each unique vegetation class was developed based on the percent of FIA sub-plots rated as None, Low, Moderate, and High root disease severity in each unique vegetation class (see Appendix). The resulting root disease hazards for each unique combination of Bailey’s Ecoregion, DomMid40 and PVT were then mapped using R1 VMap for the existing vegetation, overlaid with the regional PVT layer and Bailey’s Ecoregion boundaries to map root disease hazard for western Montana and northern Idaho.

Results

Root disease severity from FIA sub-plots

Based on the FIA data analysis, almost 5.7 million acres of Northern Region NF lands west of the Continental Divide currently have some level of root disease, and over 2.2 million acres of NF lands are rated as having moderate or high severity root disease (Figure 4). Moderate root disease severity means root disease is responsible for 10 to 50% canopy reduction, while high root disease severity means root disease is responsible for over 50% canopy reduction. The proportion of none, low, moderate and high root disease severity by National Forest (NF) is shown in Figure 5.

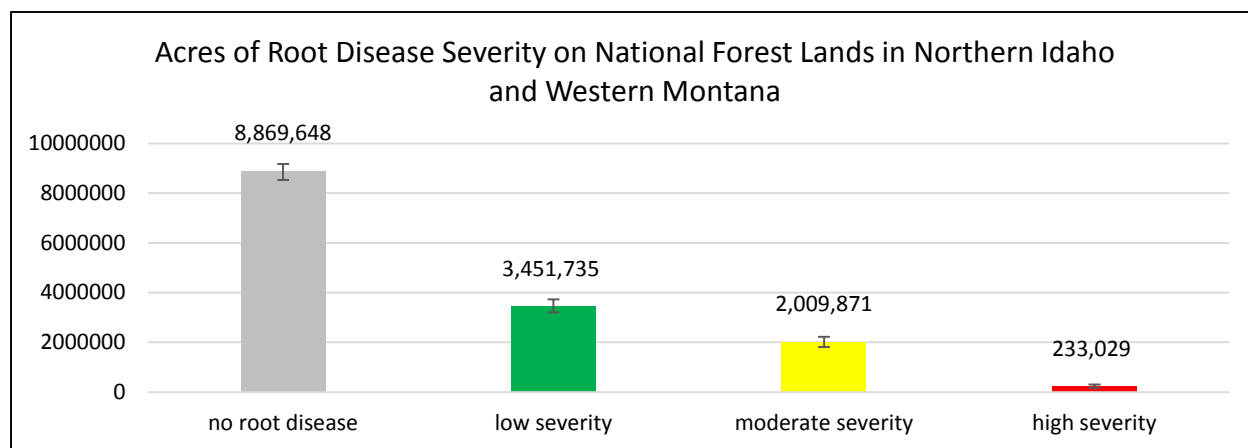


Figure 4. Acres of root disease severity that currently exists on National Forest Lands in northern Idaho and western Montana, as determined by annual inventory data from the FIA sub-plots, collected 2003 to 2007 (90% error bars).

The proportion and total acres of none, low, moderate and high root disease severity by PVT are shown in figures 6 and 7. The PVT with the most overall acres is abla2 (Figure 7). High root disease severity is on 2.99% of the acres in this PVT. The other PVTs with proportions of high root disease severity greater than 1% are abgr1 (3.53%), abla1 (3.26%), abla3 (2.42%), tsme2 (2.38%), abgr2 (2.10%), abgr3 (1.95%), tshe (1.37%), and psme2 (1.32%). The PVTs with the highest proportion of acres with any level of root disease are tshe (63.47%) and thpl1 (63.46%).

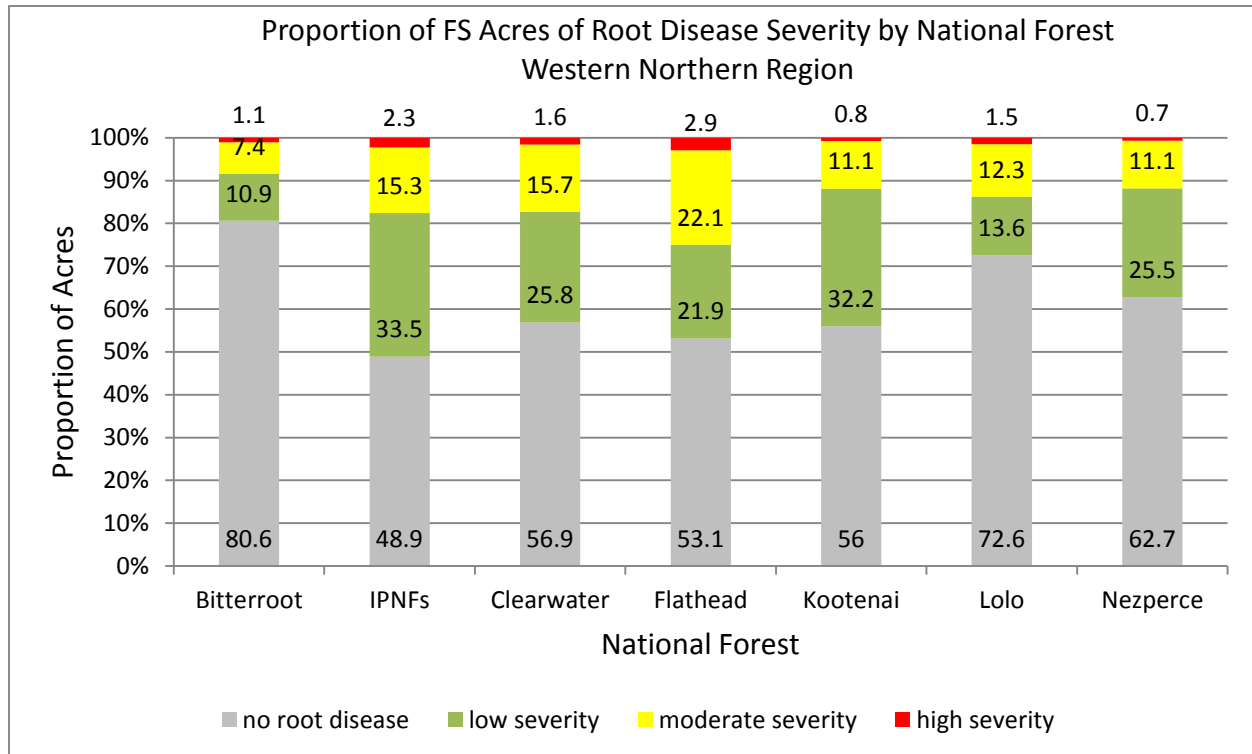


Figure 5. Proportion of National Forest acres of root disease severity as determined by FIA sub-plot data.

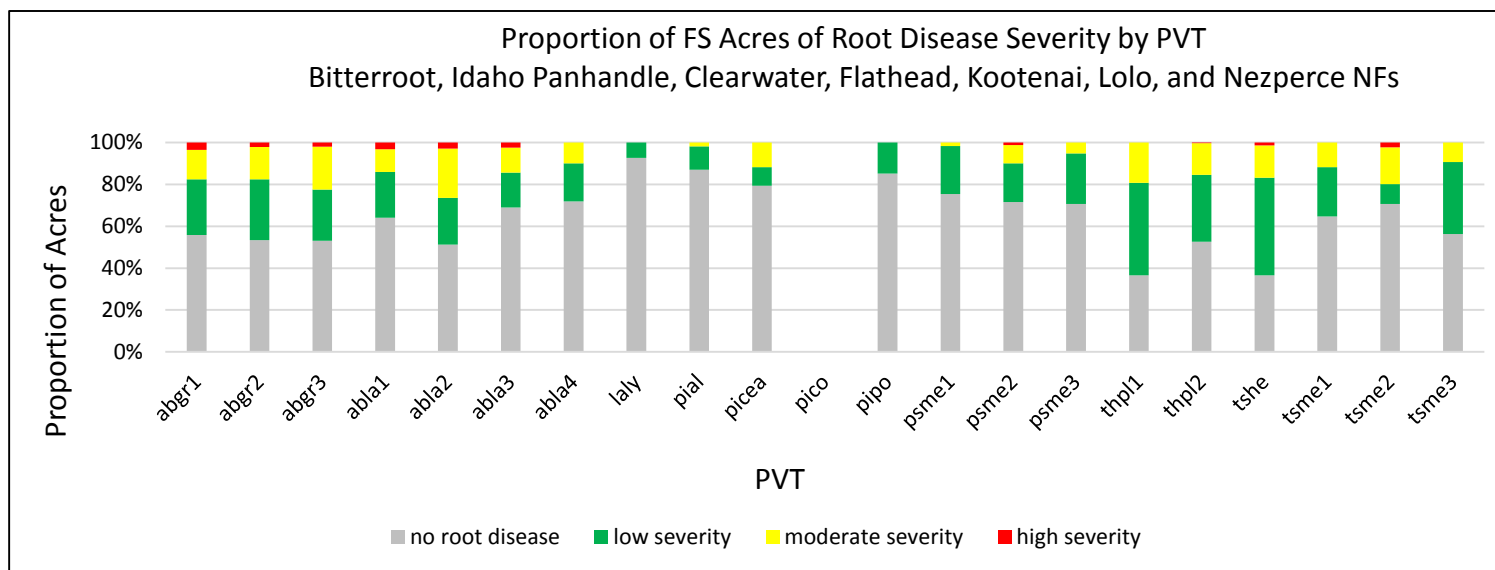


Figure 6. Root disease severity as proportion of FS acres for the National Forests west of the Continental Divide in the Northern Region.

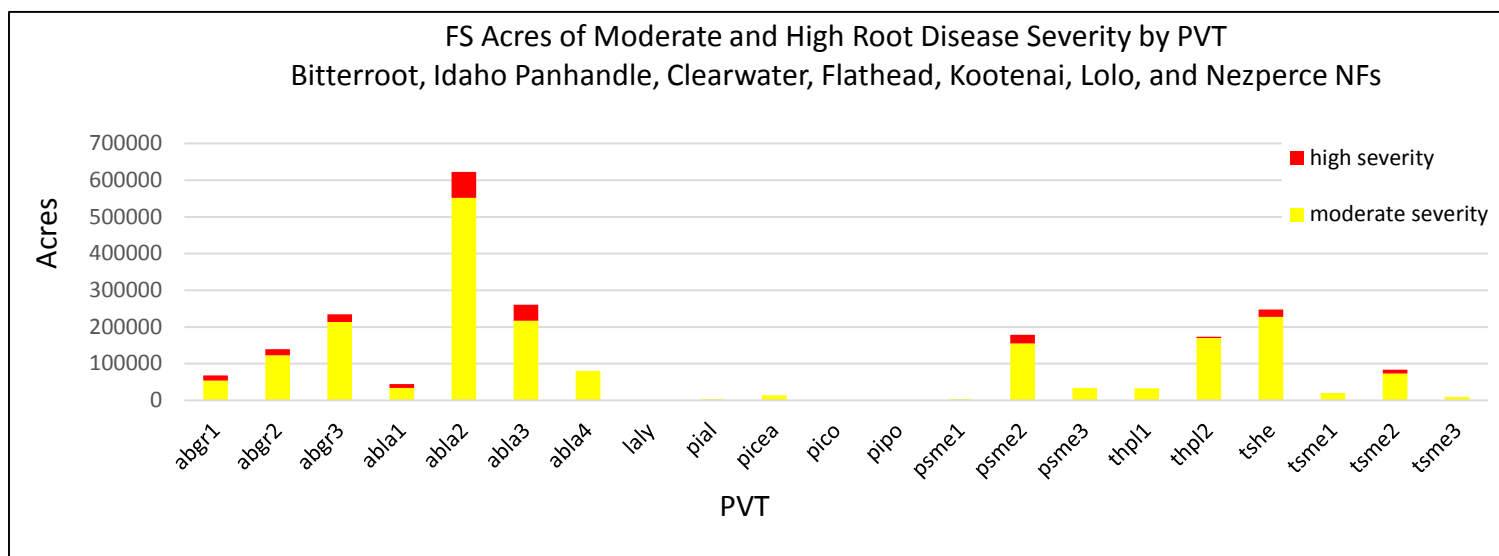


Figure 7. National Forest acres of moderate and high root disease severity on NFs west of the Continental Divide in the Northern Region.

Root disease hazard calculated from severity

A root disease hazard rating was applied to each unique combination of Bailey's Ecoregion, PVT, and DomMid40 dominance type resulting in over 11.6 million VMap acres in western Montana and northern Idaho having some level of root disease hazard (Figure 8). The spatial

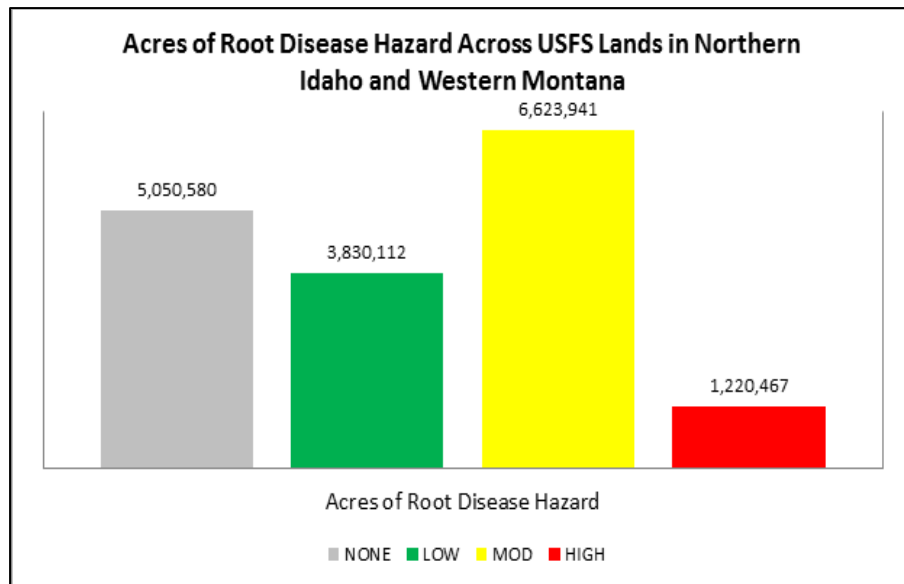


Figure 8. VMap Acres of root disease by hazard across National Forests in northern Idaho and western Montana, as determined by calculating hazard from root disease severity collected on FIA sub-plots, then applying to unique combinations of Bailey's ecoregion, DomMid40 and PVT across the area. Hazard is defined as the probability that root disease has the potential to exist, and the likelihood it will have an impact if it does exist on the ground.

depiction of root disease hazard for western Montana and northern Idaho can be seen in Figure 9.

The proportion of VMap acres of none, low, moderate, and high root disease hazard by PVT are shown in Figure 10, and the actual acres of moderate and high root disease hazard are shown in Figure 11. Grand fir and subalpine fir PVTs, as well as tshe and tsme2 PVTs, have notable proportions of acres with high root disease hazard.

This root disease hazard analysis will be updated as necessary, such as when VMap layers are updated, when analysis of future FIA annual inventory data indicates a change in the distribution of root disease severity, or when the R1 Potential Vegetation Classification is updated. Any adjustments to the spatial depiction of root disease hazard in northern Idaho and western Montana will be made at that time.

This root disease hazard analysis is appropriate at a mid-scale planning level and would need to be used with caution at smaller scales. Example analyses for incorporating these data into planning efforts at multiple scales are included in the Discussion section.

Western Region 1 Root Disease Hazard Rating

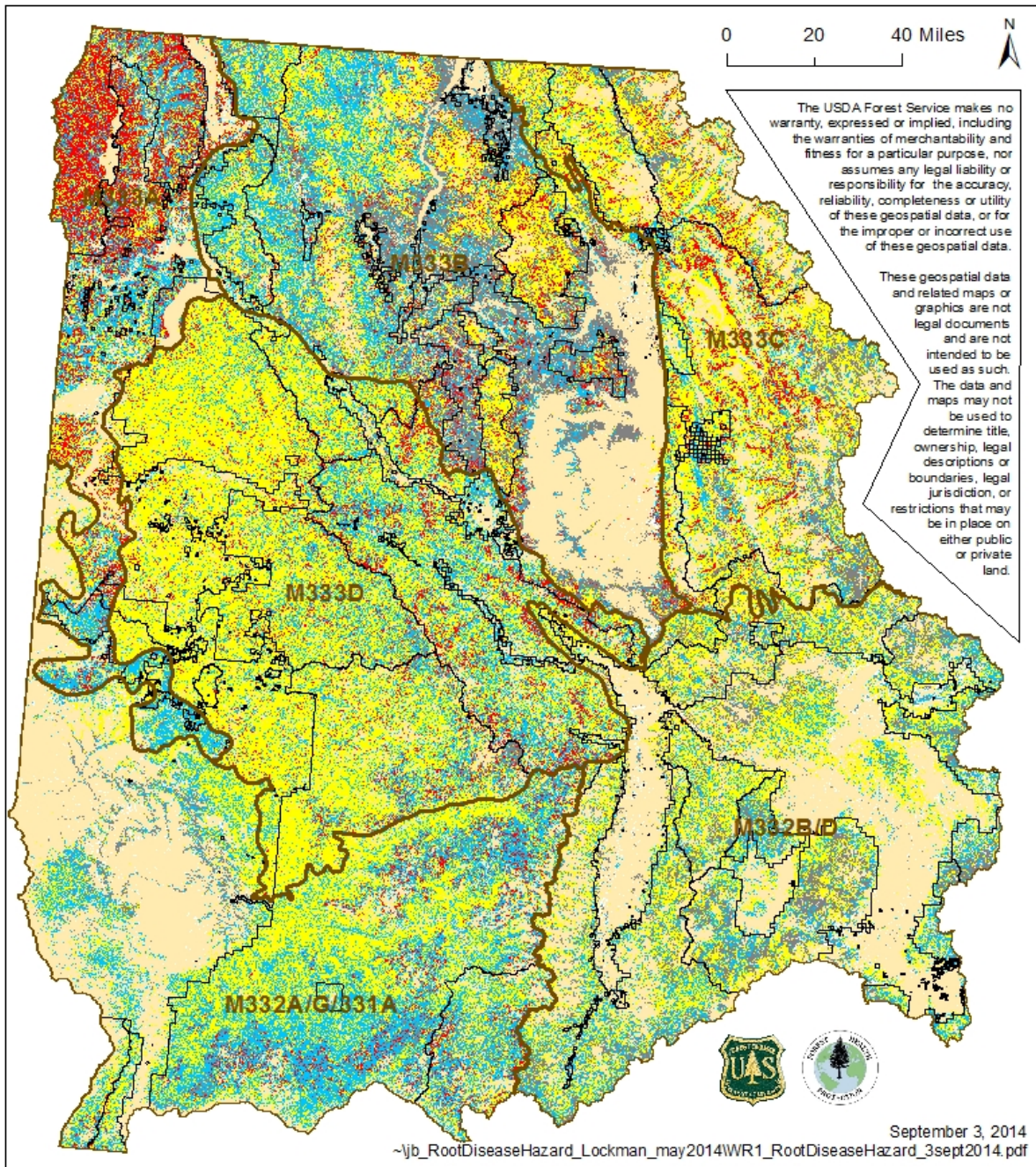
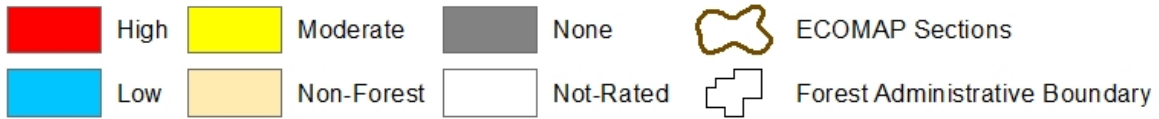


Figure 9. Regional root disease hazard map for northern Idaho and western Montana.

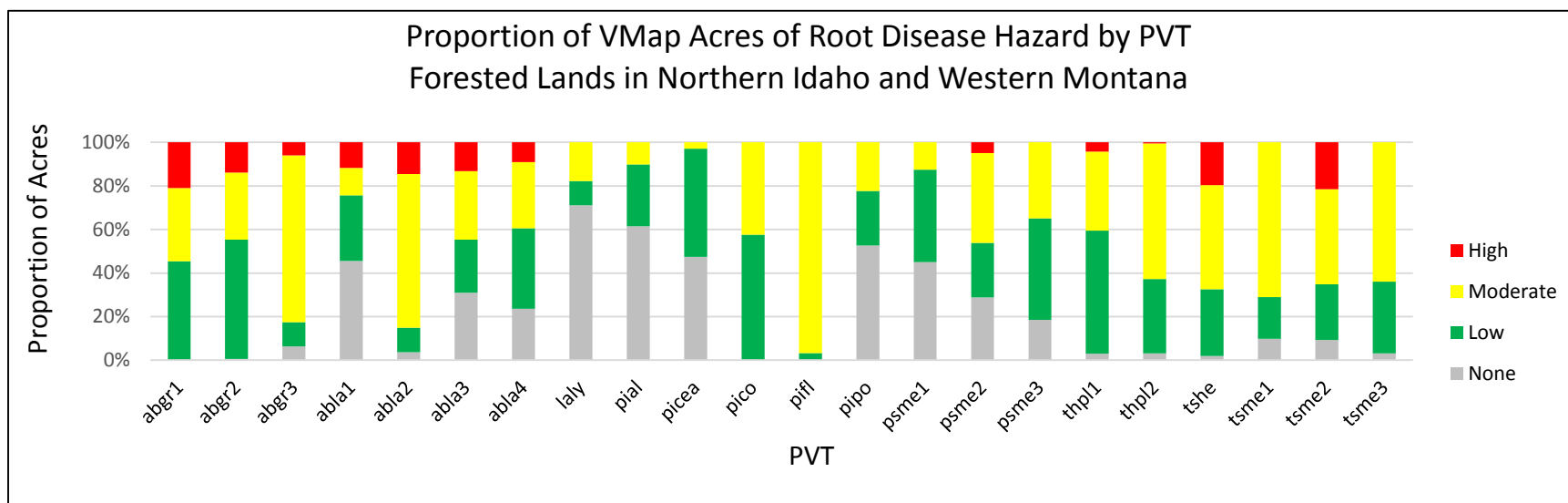


Figure 10. Proportion of VMap acres of root disease hazard by PVT on all forested lands west of the Continental Divide in the Northern Region.

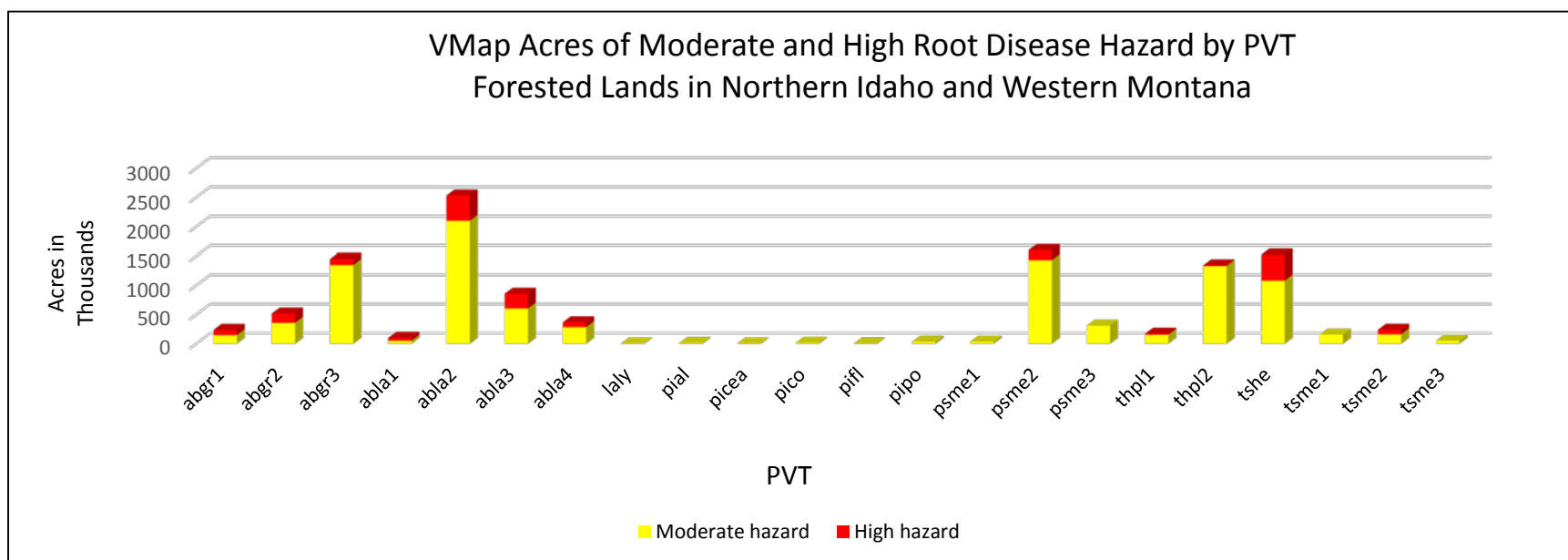


Figure 11. VMap acres of moderate and high root disease hazard on all forested lands west of the Continental Divide in the Northern Region.

Although NIDFRA maps for root disease risk are available (Krist and others 2014), this current root disease hazard analysis is based on root disease data collected on regional FIA sub-plots, and may be more appropriate to use at the Regional and smaller scales. The exception is one eastside forest, the Gallatin NF, which was not included in this analysis, but was included in the NIDFRA risk mapping effort for predicted basal area loss due to root disease.

Discussion

Root diseases are the most damaging group of diseases that cause volume loss of forest trees in the United States (Lockman and Kearns 2016). Root disease severity collected on the FIA sub-plots provides the most accurate, systematically obtained, mid-scale assessment of root diseases available in the Northern Region. Almost 5.7 million acres of Northern Region NF lands west of the Continental Divide have some level of root disease, and over 2.2 million acres of NF lands are rated as having moderate or severe root disease. Root diseases are undeniably significant agents of change on the landscape in the Northern Region west of the Continental Divide.

Summarizing acres of root disease severity by FIA sub-plots should not be scaled down below the forest level- there are too few plots to make it meaningful at a smaller scale. But, the acres of root disease severity by DomMid40/PVT classes at the NF level provide a guide for the potential root disease severity by DomMid40/PVT classes during area analyses.

Root disease hazard by R1-VMap spatial layer may be most appropriate for prioritizing areas for more detailed analysis. Root disease hazard indicates a probability of root disease occurring and the potential impact possible from root disease. A R1-VMap polygon with a root disease hazard greater than "None" indicates there is a good likelihood root disease occurs in that PVT/DomMid40 class on the ground; and the higher the hazard rating (low<mod<high), the greater the likelihood root disease will have an impact where it does exist. It should alert the user to the expected relative importance of root disease in an area and to develop management options compatible with managing forests with root disease. The proportion of polygons by root disease hazard will dictate the necessity of evaluating root disease severity at the stand or plot level. Root disease severity ratings can be done on the ground using plot level ratings, or by using aerial photos to rate stands for root disease severity (Hagle 2011; 1992).

If an administrative area has a more accurate local spatial data set of habitat types (PVTs) and/or a spatial data set of vegetation classes similar to those used in this analysis, then these root disease hazards can be applied to this local data and should result in a more accurate hazard map. Root disease hazard by VMap spatial layer, as well as bark beetle hazards, have been summarized by 6th code HUC-12 sub-watersheds and a user guide will be published soon (Egan and others unpublished data). The geodatabase of the sub-watershed summaries by agent are available in the Regional GIS library, but until the user guide is published, potential users should contact the Missoula FHP office to discuss appropriate applications. Root disease hazard summarized at 6th code HUC-12 sub-watershed may be most appropriate at the Regional and Forest level, but may also have utility at the analysis area level if multiple sub-watersheds occur within the analysis area.

Following are examples of how root disease severity and hazard can be downscaled to an individual administrative unit to provide more specific data.

Forest Level Analysis: Flathead National Forest

Root disease severity from FIA sub-plots

Root disease severity ratings measured on FIA sub-plots on the Flathead National Forest were collapsed into the four severity classes, and the acres represented by each FIA sub-plot were then calculated. The Flathead NF has over 68,000 acres with high root disease severity. These acres have lost over 50% of their overstory to root disease. Over 521,000 acres have lost at least 10% and up to 50% of their canopy to root disease (moderate severity), and almost 517,000 acres have lost at least some root disease with canopy losses up to 10% (low severity). Data from the FIA sub-plots indicate there are just over 1,250,000 acres with no root disease on the Flathead NF (Figure 12).

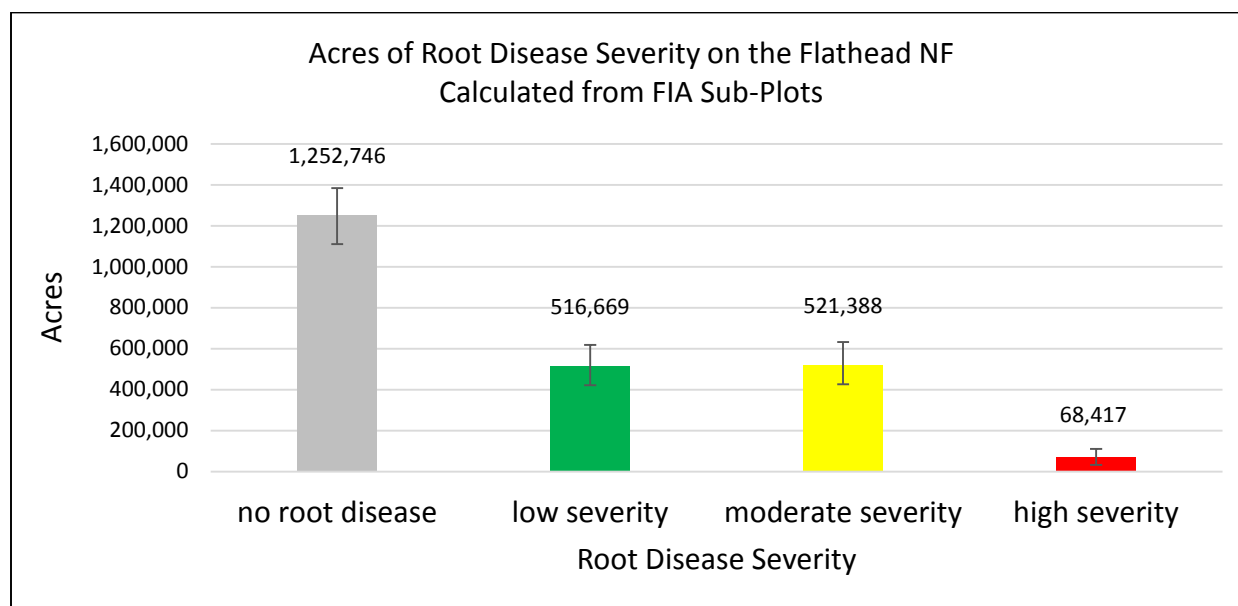


Figure 12. Acres of root disease by severity class as determined by FIA sub-plot data on the Flathead NF (90% error bars).

Acres for each root disease severity class were also calculated for each PVT present on each National Forest. Due to the difference in the partition of interest for the FIA sub-plots, calculations of the total acres for each root disease severity class by PVT differ slightly than the calculations of the total acres for just root disease severity class (see Bush and others 2016 for further clarification). Root disease occurs on many PVTs on the Flathead NF, but the most severe levels of root disease are found in four PVTs: abgr3, abla1, abla2, and abla3 (Table 1; Figure 13). Proportion of acres with root disease on these PVTs are notable. Nearly 69% of abgr3 PVT acres, over 66% of abla1 PVT acres, almost 65% of abla2 PVT acres, and just over 41% of abla3 PVT acres have some level of root disease (Figure 14). It is also worth mentioning that abla2 and abla3 are the most represented PVTs on the Forest. Although not a common PVT, psme1 is notable for having some level of root disease on all acres.

Table 1. Acres of root disease severity by PVT as determined by FIA sub-plot data on the Flathead NF. Acres of the most severe root disease and the PVTs where they occur are shaded pink.

PVT	Root Disease Severity			
	None	Low	Moderate	High
abgr2	12822	0	0	0
abgr3	16027	12822	19233	3205
abla1	25643	9616	32055	9616
abla2	336574	224386	336574	51284
abla3	285288	128220	70522	3206
abla4	48082	19233	35260	0
laly	19233	6411	0	0
pial	128218	12822	0	0
picea	51287	9616	3205	0
pico	12822	0	0	0
psme1	0	9616	3205	0
psme2	118602	12822	9616	0
psme3	32055	44876	0	0
thpl2	12822	0	12822	0
tshe	19233	6411	0	0
unknown	134629	19233	0	0
TOTAL	1253337	516084	522492	67311

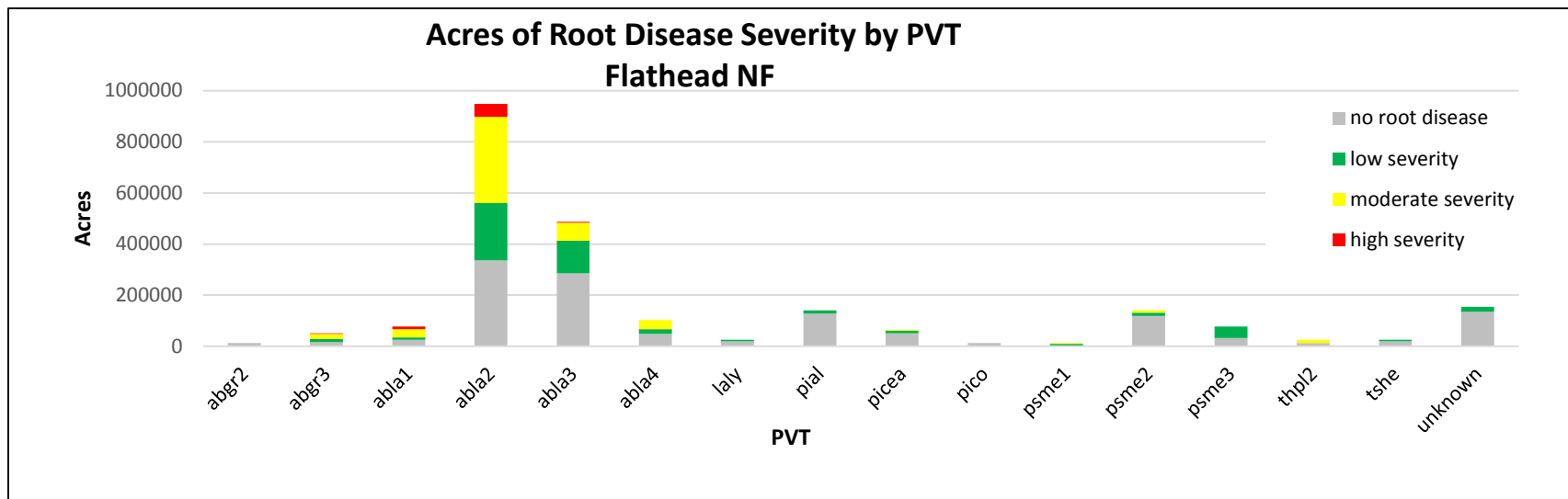


Figure 13. Acres of root disease severity for each PVT as determined by FIA sub-plot data on the Flathead NF.

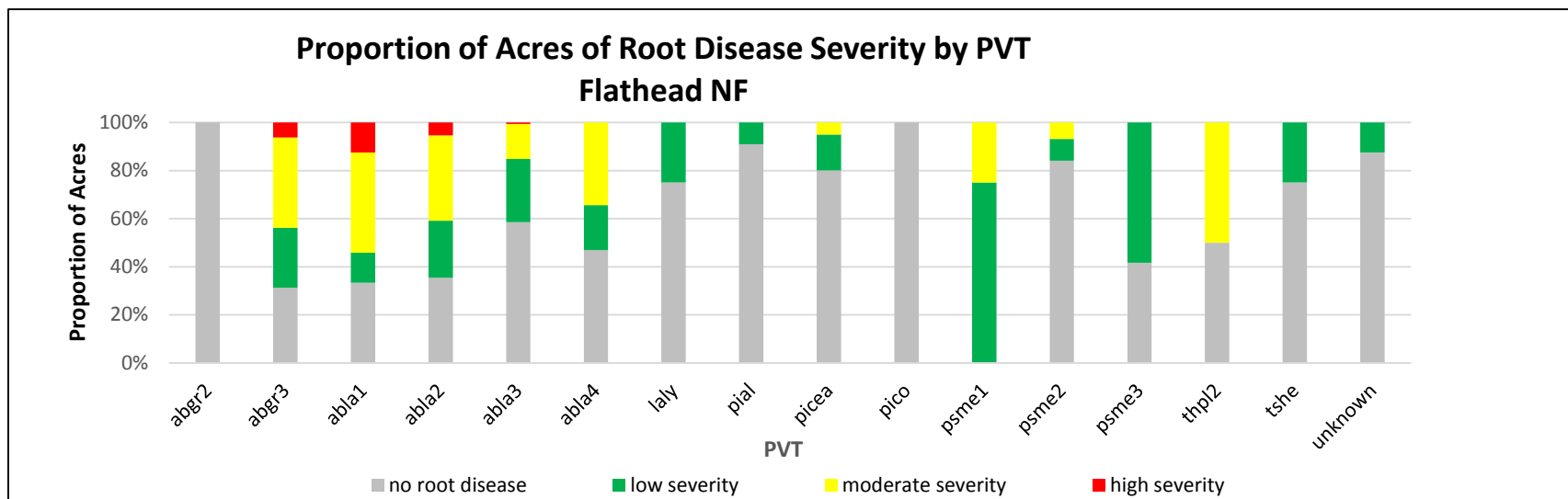


Figure 14. Proportion of PVT acres of root disease severity as determined by FIA sub-plot data on the Flathead NF.

Root disease hazard using VMap spatial data

The Regional VMap root disease hazard map was clipped to the Flathead National Forest boundary (Figure 17) and summarized accordingly. Over 245,000 acres have high root disease hazard within the boundaries of Flathead NF (Table 2; Figure 15). High root disease hazard on the Flathead NF occurs mainly on abgr2, abgr3, abla1, abla2, and abla3 PVTs, and minimal acres also occur on psme2 and thpl1 PVTs (Table 2; Figure 16). Although no high root disease severity was recorded on FIA sub-plots with abgr2, psme2, or thpl1 PVTs on the Flathead NF (Table 1), high root disease severity was recorded on sub-plots in these PVTs within the larger Bailey's Ecoregion that includes the Flathead NF. There is a high likelihood root disease exists on the ground in these PVT/DomMid40 classes. Although not all acres within the high hazard classes will have root disease, these are the classes with the greatest potential for severe root disease to occur on the ground, and where root disease is most likely to have a significant impact when it does occur. Managers should take a more detailed look at these areas and be prepared to plan for long term consequences of having root disease on the site.

Most of the forested lands have moderate root disease hazard (nearly 1.1 million acres; Table 2; Figures 15), which indicates root disease is a major agent of change on the Flathead NF. These PVT/DomMid40 classes have both low and moderate levels of root disease, but the potential for moderate levels of root disease to occur in these classes is great.

Over 65% of forested lands within the boundaries of the Flathead NF (over 1.2 million acres) have moderate or high root disease hazard (Table 2). Detailed analyses on the Forest should consider the presence and severity of root disease when planning any management activities where root disease hazard is moderate or high.

Low root disease hazard occurs in PVT/DomMid40 classes covering over 313,000 acres (Table 2; Figures 15 and 16), indicating root disease likely occurs on the ground in these classes, but at low severity levels. These classes should be evaluated for root disease severity, but root disease will likely have less impact in these classes than those with moderate or high hazard.

No root disease hazard occurs on over 366,000 acres on the forest. No root disease hazard means there is a very low likelihood of root disease existing on the ground in these PVT/DomMid40 classes. Root disease may still be found within these classes, but data indicates it is unlikely.

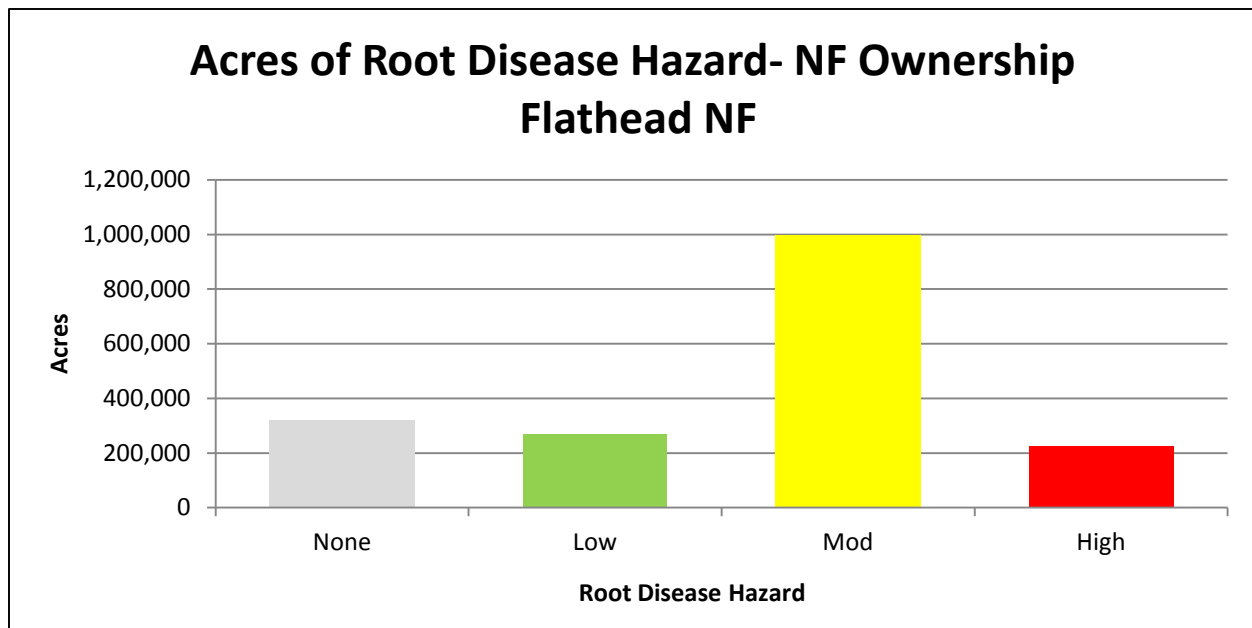


Figure 15. VMap acres of root disease hazard across Flathead National Forest lands, as determined by calculating hazard from root disease severity collected on FIA sub-plots, then applying to unique combinations of Bailey's ecoregion, DomMid40 cover type and PVT across the area.

Table 2. Acres of root disease hazard by PVT for all ownerships within the boundaries of the Flathead NF. Larger acreages of high hazard exist in PVTs shaded pink.

GIS VMap Acres of Root Disease Hazard					
Flathead NF					
PVT	None	Low	Moderate	High	Grand Total
abgr2	4	6969	3072	5760	15806
abgr3	6991	2200	48802	6159	64152
abla1	19141	15308	7676	8190	50315
abla2	5770	4335	700186	219502	929794
abla3	110019	121638	112427	5184	349269
abla4	29247	180	147625	0	177051
laly	8048	66	1151	0	9265
pial	37579	10270	4087	0	51936
picea	34909	14613	1323	0	50845
pico	0	150	98	0	248
pipo	18	8	260	0	286
psme1	5807	3741	1833	0	11381
psme2	84774	64144	13743	596	163257
psme3	20184	25103	7808	0	53095
thpl1	0	861	1121	34	2016
thpl2	2324	39024	14045	4	55397
tshe	34	4810	4562	0	9405
tsme2	1966	28	1651	0	3645
Grand Total	366815	313449	1071470	245431	1997164

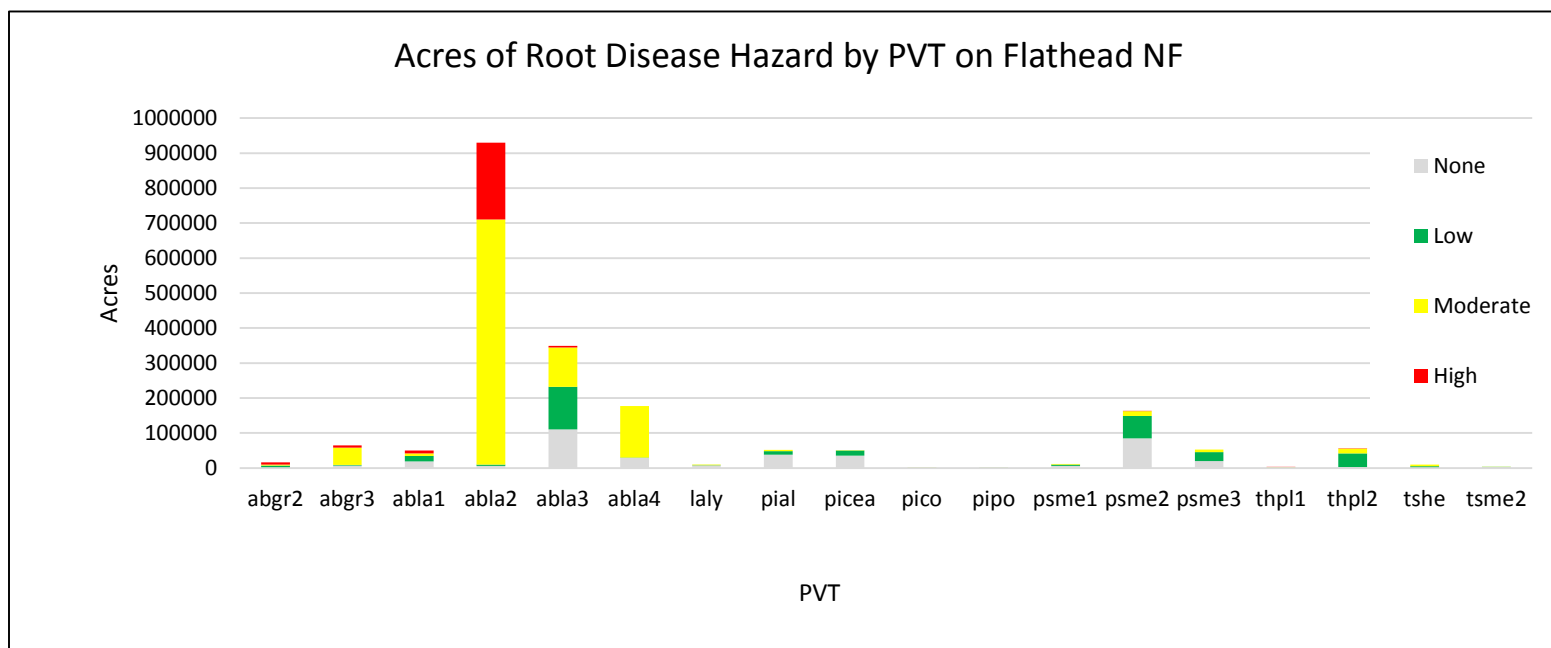


Figure 16. VMap acres of root disease hazard by PVT for all ownerships within the boundaries of Flathead National Forest as determined by calculating hazard from root disease severity collected on FIA sub-plots, then applying to unique combinations of Bailey's ecoregion, DomMid40 cover type and PVT across the area.

Flathead NF Root Disease Hazard Rating

The USDA Forest Service makes no warranty, expressed or implied, including the warranties of merchantability and fitness for a particular purpose, nor assumes any legal liability or responsibility for the accuracy, reliability, completeness or utility of these geospatial data, or for the improper or incorrect use of these geospatial data.

These geospatial data and related maps or graphics are not legal documents and are not intended to be used as such. The data and maps may not be used to determine title, ownership, legal descriptions or boundaries, legal jurisdiction, or restrictions that may be in place on either public or private land.



-  Forest Administrative Boundary
-  High
-  Low
-  Moderate
-  Non-Forest
-  None
-  Not-Rated

August 27, 2014
~\jb_RootDiseaseHazard_Lockman_may2014\FlatheadRDH_27aug2014.pdf



0 10 20 Miles

Figure 17. Regional root disease hazard map clipped to the Flathead NF administrative boundary.

Project Area Analysis: Jam Cracker Analysis Area (AA), Superior RD, Lolo National Forest

The Regional VMap root disease hazard map was clipped to the Jam Cracker AA and is displayed in Figure 18. The Jam Cracker AA reflects a trend similar to the Lolo NF, and has almost 39,000 acres of moderate or high root disease hazard, which equals just under 60% of the area (Table 3). More details on the root disease hazard analysis for Jam Cracker AA, as well as bark beetle hazard analysis, by vegetation classes as defined by the District can be found in Lockman and Steed (2016).

Table 3. Acres of root disease hazard by potential vegetation type (PVT) within the Jam Cracker Analysis Area, Lolo NF. Larger acreages of high hazard exist in abla3 and psme2 PVTs (shaded pink).

GIS VMap Acres of Root Disease Hazard by PVT Jam Cracker Analysis Area, Lolo NF					
PVT	None	Low	Moderate	High	Grand Total
abgr1		51	63	189	303
abgr2		3431	804		4235
abgr3	218	66	1244	271	1799
abla1	40	36			76
abla2	129	2575	606	452	3763
abla3	546	211	3630	4924	9311
abla4	464	4	54		522
pico		13	15		29
pipo	89		90		179
psme1	967	979	353		2299
psme2	421	11190	21512	2302	35425
psme3	562	3787	301		4650
thpl2		854	2049		2903
tsme2		22	48	16	86
Grand Total	3435	23221	30770	8154	65580

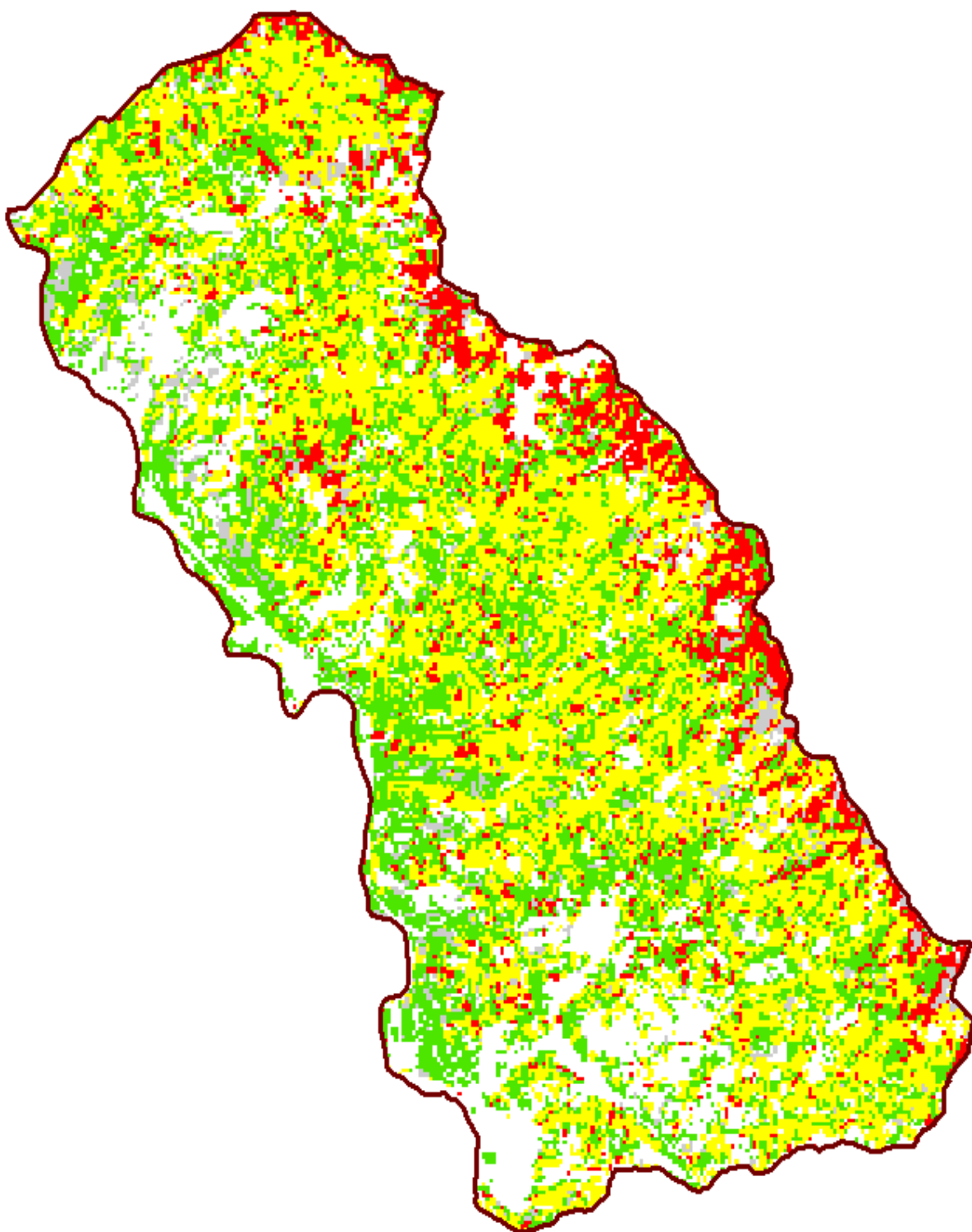


Figure 18. Regional root disease hazard map clipped to the Jam Cracker Analysis Area administrative boundary. Red= high hazard, yellow= moderate hazard, green= low hazard, grey= no hazard, white= non-forest or not rated.

Over 8,000 acres of high root disease hazard exist in Jam Cracker, with the majority of these acres occurring on abla3 and psme2 potential vegetation types (PVT) (Figure 19 and Table 3). These high hazard acres are concentrated in the eastern portion of Jam Cracker, which is also the upper elevations of the AA. The majority of the high hazard occurs in the PVT/DomMid40 class of psme2/MX-PSME (Figure 20). Although not all acres within the high hazard class have root disease, this hazard class has the greatest potential for severe root disease to occur on the ground and cause significant impacts where it does occur.

Nearly half of the Jam Cracker AA has moderate root disease hazard (over 30,000 acres), which indicates root disease is a major agent of change in this area. These acres appear to be concentrated in the mid elevations of the analysis area. The PVT/DomMid40 classes rated as moderate hazard have both low and moderate levels of root disease, but the potential for moderate levels of root disease to occur in these classes is great. Detailed analyses should consider the presence and severity of root disease when planning management activities where root disease hazard is moderate or high.

Low root disease hazard occurs in PVT/DomMid40 classes covering over 23,000 acres, indicating that root disease likely occurs on the ground in these classes, but at low severity levels. These classes should be evaluated for root disease severity, but root disease may have less impact in these classes than those with moderate or high hazard.

No root disease hazard occurs on almost 3,500 acres of the AA. No root disease hazard means there is a very low likelihood of root disease existing on the ground in these PVT/DomMid40 classes. Root disease may still be found within these classes, but data indicates it is unlikely. Just over 17,000 acres were mapped as non-forest in this analysis.

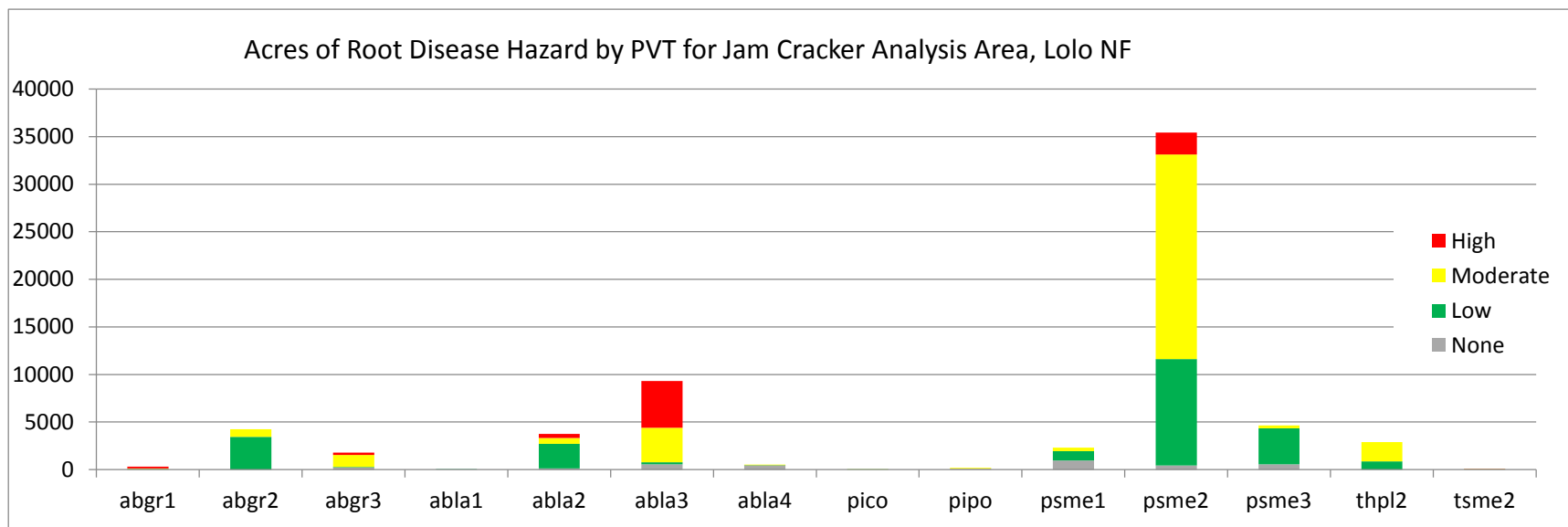


Figure 19. VMap acres of root disease hazard by PVT within the Jam Cracker Analysis Area, Lolo NF.

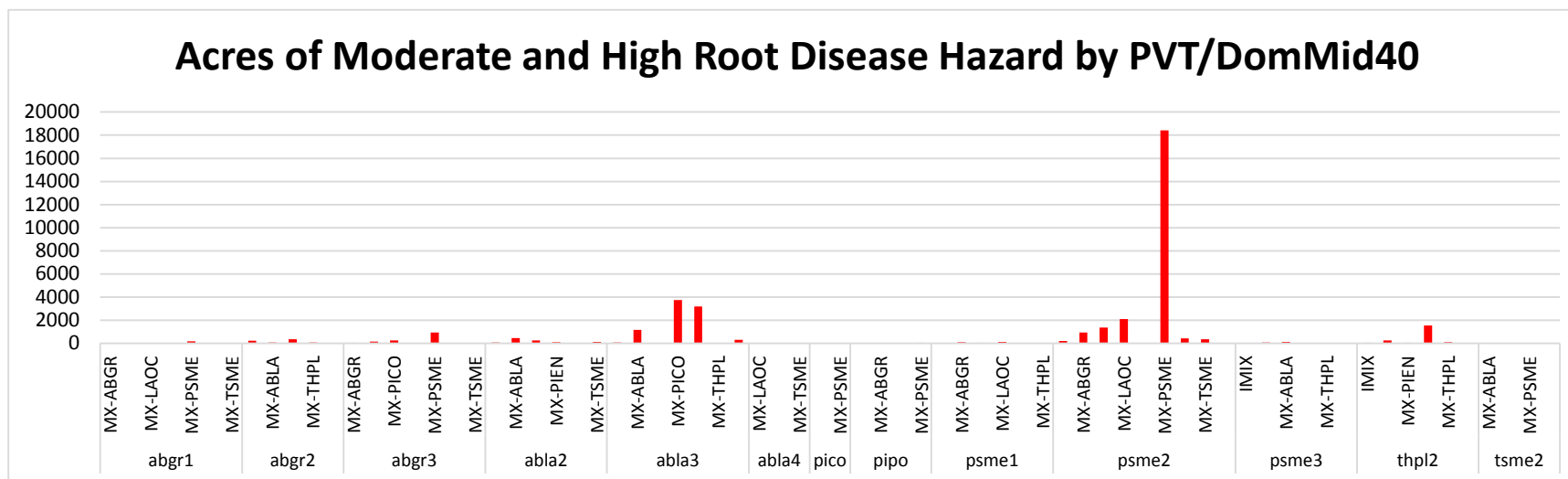


Figure 20. Vmap acres of moderate and high root disease hazard by PVT and DomMid40 classes within the Jam Cracker Analysis Area, Lolo NF

Acknowledgements:

The authors would like to acknowledge Heather Weldon for providing mapping and VMap acreage calculations; Brian Reyes and JD Zeiler for assistance in analyzing the FIA plots and calculating acreages; Joel Egan and Brytten Steed for provided support and leadership in hazard rating work within Forest Health Protection, and Gregg DeNitto, Brytten Steed and Marcus Jackson for helpful reviews of the draft paper.

Citations:

- Anonymous. 2013. Interior West Forest Inventory and Analysis P2 Field Procedures, Version 6.00. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Forest Inventory and Analysis, Ogden, UT. 446 p.
http://www.fs.fed.us/rm/ogden/data-collection/pdf/iwfia_p2_60.pdf
- Anonymous. 2015. R1 Inventory Look-up Tables Database. Report #15-07 v2.0. Missoula, MT: U.S. Department of Agriculture, Forest Service, Northern Region, Vegetation Classification, Mapping, Inventory, and Analysis. 11 p.
<http://fsweb.r1.fs.fed.us/forest/inv/classify/index.shtml>
- Bailey, R. G. 1995. Descriptions of the Ecoregions of the United States, 2nd edition Washington, DC: U.S. Department of Agriculture Forest Service, Miscellaneous Publication No. 1391 (revised). 108 pages. <http://www.fs.fed.us/land/ecosysmgmt/>
- Barber, J., R. Bush, and D. Berglund. 2011. The Region 1 Existing Vegetation Classification System and its Relationship to R1 Inventory Data and Map Products. Report 11-10. Missoula, MT: U.S. Department of Agriculture, Forest Service, Northern Region, Vegetation Classification, Mapping, Inventory and Analysis. 39 p.
http://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb5332073.pdf
- Barber, J., Brown, S.R., Jr., Ahl, R. 2012. Mid-level and Base-level Databases of the R1 Existing Vegetation (VMap) Products. Numbered Report 12-38. U.S. Department of Agriculture, Forest Service, Northern Region, Engineering. 12p.
- Bush, R., Reyes, B., Zeiler, JD. 2016. R1 Summary Database Reports and Utilities User's Guide. Numbered Report 16-2 v3.2. U.S. Department of Agriculture, Forest Service, Northern Region, Vegetation Classification, Mapping, Inventory and Analysis; Missoula, Montana. 77 p.
- Byler, J. W., Marsden, M. A., and Hagle, S. K. 1990. The probability of root disease on the Lolo National Forest, Montana. Can. J. For. Res. 20: 987-994.
- Egan, J. and others – unpublished data. (see r1_fhtet_dougfirbeetle_huc6_summary R1 geodatabase metadata).
- Hagle, S. 1985. Monitoring root disease mortality: establishment report. Report No. 85-27. U.S. Department of Agriculture, Forest Service, Northern Region, State and Private Forestry, Forest Health Protection; Missoula, Montana. 11 p.
- Hagle, S.K. 1992. Rating for Root Disease Severity. IN: Proc. of the Fortieth Western International Forest Disease Work Conference. Durango, Colorado. July 1992. Pp. 80-86.

- Hagle, S.K.; Tucker, G.J.; Anderson, M.A. 2016. Root disease and other mortality agents on the Clearwater National Forest: 22-year results from Mex Mountain growth and mortality permanent plots. Report No. 16-05. U.S. Department of Agriculture, Forest Service, Northern Region, State and Private Forestry, Forest Health Protection; Missoula, Montana. 29 p.
- Hagle, S. 2011. Root Disease Severity Rating: On Ground Plots. U.S. Department of Agriculture, Forest Service, Northern Region, Forest Health Protection, Missoula, MT. R1-11-18, 2 pp. http://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb5162982.pdf
- Hagle, S.K.; Schwandt, J.W.; Johnson, T.L.; Kegley, S.J.; Randall, C.S.B.; Taylor, J.E.; Lockman, I.B.; Sturdevant, N.J.; Marsden, M.A. 2000. Succession Functions of Forest Pathogens and Insects: Ecosections M332a and M333d in Northern Idaho and Western Montana. Volume 2: Results. FHP Report No. 00-11. U.S. Department of Agriculture, Forest Service, State and Private Forestry, Forest Health Protection, Northern Region; Missoula, Montana. 262 p.
- Krist, Jr., F.J.; Ellenwood, J.R.; Woods, M.E.; McMahan, A.J.; Cowardin, J.P.; Ryerson, D.E.; Sapio, F.J.; Zweifler, M.O.; Romero, S.A. 2014. National Insect and Disease Forest Risk Assessment: 2013-2027. FHTET-14-01. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Forest Health Technology Enterprise Team. 199 p.
- Lockman, I. Blakey; Kearns, Holly S.J., eds. 2016. Forest root diseases across the United States. Gen. Tech. Rep. RMRS-GTR-342. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 55 p.
- Lockman, I.B.; Steed, B. 2016. Disease and Insect agents in Jam Cracker Analysis Area, Lolo National Forest. MFO-TR-15-47. Missoula, MT: U.S. Department of Agriculture, Forest Service, Northern Region, Forest Health Protection. 36 p.
- Milburn, Amanda, B. Bollenbacher, M. Manning, R. Bush. 2015. Region 1 Existing and Potential Vegetation Groups used for Broad-level Analysis and Monitoring. Report #15-4 v1.0. Missoula, MT: U.S. Department of Agriculture, Forest Service, Northern Region, Vegetation Classification, Mapping, Inventory, and Analysis. 11 p. http://fsweb.r1.fs.fed.us/forest/inv/r1_tools/R1_allVeg_Groups.pdf

Citation for this publication:

- Lockman, B; Bush, R.; Barber, J. 2016. Assessing Root Disease Presence, Severity and Hazard in Northern Idaho and Western Montana Using Forest Inventory and Analysis (FIA) Plots and the USFS Northern Region VMap Database. Report No. 16-07. Missoula, MT: U.S. Department of Agriculture, Forest Service, Northern Region, State and Private Forestry, Forest Health Protection. 26 p.

Appendix. Criteria for assigning root disease hazard to each unique vegetation class (Bailey's ecoregion, DomMid40 and PVT) based on root disease severity collected on FIA sub-plots.

Hazards were assigned to each unique combination in the following order:

1. "Hazard= None" if 80% or more of all FIA sub-plots within the vegetation class had root disease severity ratings of NONE, and no sub-plots with a rating of HIGH.
 - a. EXCEPTION: If there are sub-plots with a rating of HIGH after meeting the criteria for None, then those ratings were dealt with individually (only 1 class, and it was assigned LOW hazard).
 - b. All sub-plots assigned "None" were then removed and remaining sub-plots are referred to as non-zero sub-plots (sub-plots with root disease ratings of LOW, MOD, or HIGH) and were analyzed for the next steps.
2. "Hazard= High" if 8% or more of the non-zero FIA sub-plots (low+moderate+high) within the vegetation class had root disease ratings of HIGH and 3% or more of all FIA sub-plots (none+low+moderate+high) within the vegetation class had root disease ratings of HIGH.
 - a. EXCEPTION: If above criteria for High Hazard is met, but at least 75% of the sub-plots have a rating of LOW, then hazard rating is "Moderate" (One exception to this was M333B, abgr2, Mx-PSME, which has 2.38% of all sub-plots in high and 8.33% of non-zero sub-plots in high- it was assigned "High".)
3. "Hazard= Low" if greater than 75% of non-zero FIA sub-plots within the vegetation class had root disease ratings of LOW; OR if 66.67% to 75% of the FIA sub-plots within the vegetation class had root disease ratings of LOW and no sub-plots have a rating of HIGH.
4. "Hazard= Moderate" if 66.67% to 75% of the non-zero FIA sub-plots within the vegetation class had root disease ratings of LOW and at least 1% of sub-plots have a rating of HIGH, OR if less than 66.67% of the non-zero FIA sub-plots within the vegetation class had root disease ratings of LOW and the vegetation class had not already been assigned HIGH.
5. When cover type is herbaceous, shrub, water, sparsely vegetated VMap polygons were labeled "Non-Forest".
6. When PVT is herbaceous, shrub, water, rock, or agriculture, then the VMap polygons were labeled "Not Rated".